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MANUFACTURING METHODS AND TECHNIQUES FOR MINIATURE HIGH VOLTAGE--ETC(U)

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THIRD QUARTERLY PROGRESS REPORT

MANUFACTURING METHODS AND TECHNOLOGY REPORT

CONTRACT DAAB07-76-C-0041

MANUFACTURING METHODS AND TECHNIQUES FOR MINIATURE HIGH VOLTAGE HYBRID MULTIPLIER MODULES

PLACED BY:

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The progress of the Manufacturing Methods and Technology Program for Miniature High Voltage Multiplier Modules is described in this Third Quarterly Report.

Rectangular multipliers with various versions of capacitor banks and rectifier-substrate assemblies were fabricated and tested. Curved capacitor banks were evaluated.

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THIRD QUARTERLY PROGRESS REPORT

1 JANUARY 1977 TO 31 MARCH 1977

MANUFACTURING METHODS AND TECHNIQUES FOR MINIATURE HIGH VOLTAGE HYBRID MULTIPLIER MODULES

CONTRACT NO. DAAB07-76-C-0041

PREPARED BY: DR. MICHAEL KORWIN-PAWLOWSKI

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PURPOSE

This Contract covers component designs, mounting and interconnection techniques, tooling and test methods and other manufacturing methods and techniques required for production of rectangular and curved miniature high voltage multiplier modules. These units are to be used in low cost power supplies for second generation image intensifier tubes. The full scope and details of the specification are given in SCS-495, Appendix A to the First Quarterly Report.

Major milestones in this program consist of delivery of the following items:

(1) First and second engineering samples and test data.

(2) Production line layout and schedule.

(3) Confirmatory samples and test data.

(4) Production line set-up.

(5) Pilot production run.

(6) Production rate demonstration.

(7) Preparation and publication of a final report.

The general approach is to design and set-up a cost-effective production capability, utilizing already established device technologies and materials, and to demonstrate the production line capability to fabricate at the rate of 125 acceptable units per 40 hour week.

GLOSSARY OF SPECIAL TERMS

Capacitor bank: - Ceramic wafer with metallizations which perform the function of a number of capacitors connected in parallel (parallel bank) or in series (series capacitor bank).

Cure: - To change the physical properties of a material by chemical reaction or by the action of heat and catalyst.

Flash test: - Test consisting of instantaneous application of voltage at its specified value to the part.

Hybrid: - Technology combining thick-films (capacitor banks) with discrete devices (rectifiers).

Multiplier modules: - Device consisting of capacitor banks and rectifiers connected and packaged to perform voltage multiplication and rectification.

Pad: - The metallized area on the ceramic bank acting as a plate of a capacitor and used to make an electrical connection to it.

Rectifier: - Semiconductor device with one or more p-n junctions connected in series.

Rectifier-substrate assembly: - A substrate with rectifiers placed and secured within it.

Substrate: - Part of a multiplier module consisting of a piece of insulating material machined to accommodate the rectifiers and support the capacitor banks.

LIST OF SYMBOLS AND ABBREVIATIONS

ic	-	charging current (μA)
C_x	-	measured capacitance (pF)
D.F.	-	dissipation factor (%)
f	-	frequency (KHz)
C_i	-	input capacitance (pF)
I_L	-	load current (nA)
v_r	-	ripple voltage (V)
V_B	-	breakdown voltage (V)
V_i	-	input voltage (Vp-p)
V_o	-	output voltage (V d.c.)
η	-	efficiency (%)

1. INTRODUCTION

This report describes briefly the progress made during the period from 1 January to 31 March 1977.

In the initial effort on this program, described in the First Quarterly Report, it was possible to establish capacitor pad design that would reduce stray capacitance. Manufacture of prototype substrates assemblies demonstrated the unsuitability of the originally proposed design regarding diode pellet assembly and the complexity of jigging required in the assembly operation. A new substrate design was proposed. All effort is on the rectangular multiplier and once the major problem areas are identified and resolved, evaluation of the curved multiplier components will proceed.

In the Second Quarterly Report results of the electrical evaluation of the first prototype sample batch of capacitors were given, the choice of the rectifier was made and electrical test results were presented on the first batch of multiplier fabricated with TSK 25-250 and TSK 25-251 capacitor banks and standard four-junction rectifiers.

2. DESIGN AND CHARACTERIZATION OF THE RECTANGULAR MULTIPLIERS

The multiplier design adopted to meet this program's specifications was described in the First Quarterly Report.

Current work was concentrated on the optimization of individual components of the multiplier: the capacitors, substrate, and rectifiers, and on evaluating the rectangular multipliers fabricated with these components.

Samples of the modified design of TSK 25-250 and TSK 25-251 capacitors with dumb-bell pads and of the newer design capacitors were received on 20 January 1977. The quantities received were:

TSK 25-250 .... 19 pcs.
TSK 25-251 .... 16 pcs.
TSK 25-252 .... 12 pcs.
TSK 25-253 .... 19 pcs.
TSK 25-254 .... 8 pcs.
TSK 25-255 .... 15 pcs.

Design drawings of these capacitor banks were included in the previous quarterly report. The electrical evaluation was done and representative results are given in Tables 1 to 3.

A batch of 500, three-junction rectifiers was manufactured for use in prototype multipliers and to determine the yield levels that can be expected in large volume manufacture. An overall yield of 70% from assembly through testing at 3KV peak reverse voltage was achieved.

Three multipliers were assembled using the original design capacitors and rectifier substrates. One unit (#5) was found to be electrically defective after assembly (open circuit). Lead-pull tests were carried out on that unit, in accordance with method 211 of MIL-STD-202 as required in Test Specifications SCS-495 section 3.2.2.3. With the multiplier body held in a fixed position a force was applied to each of the two 0.020" silver leads bonded to the substrate with EPO-TEK 410 electrically conductive epoxy. Both wires passed the 10 lb pull force test. They broke, one at 11 and the other at 12 lb pull force. These tests exceed with a large margin the 0.25 lb pull force requirement of SCS-495. The remaining two good units (#6 and #7) were tested for efficiency ratings at no load and under load. In addition the units were subjected to an operational test in free air to determine at what voltages corona and arcing occurred. For test results see Table 4.

Twelve substrates were assembled using three-junction rectifiers and 0.060 inches thick glass-filled board, type G-10 supplied by Warehouse Plastics, Toronto, Ont. Some substrates were made from the machinable glass-ceramic (Macor, Code 96581 of Corning Glass) to determine the feasibility of using it as an alternative to glass-epoxy. The machinable ceramic was found difficult to work with and some 50% of the substrates broke during the various machining operations.

Fourteen multipliers of the rectangular design were assembled including:

A) 8 with original design capacitors (TSK 25-250 and TSK 25-251) and rectifier-substrate assemblies;

B) 2 with TSK 25-254 and TSK 25-255 capacitors and machinable glass-ceramic (Corning Code 9658) rectifier-substrate assemblies;

C) 4 with TSK 25-252 and TSK 25-253 capacitors and original glass-epoxy rectifier-substrate assemblies.

The results of the evaluation of these multipliers are summarized in Tables 5 and 6.

The following is an analysis of the test data on the finished multipliers with respect to the specifications of this contract:

Design A (Capacitors TSK 25-250 and TSK 25-251 with a substrate of glass-epoxy board).

2.1 Electrically all units are almost identical. They all have a calculated efficiency (by definition: Output voltage divided by AC input and the number of stages) of 97% at no load and 96% at full load of 500nA, which is much better than the required 85%.

2.2 Load regulation can be defined as the ratio of the change in output voltage to the no-load output voltage. Design "A" has a ΔV of 50 V from no load to full load, giving it a load regulation of 0.9%. Alternately, one could express the full load voltage as a percentage of no-load output for this calculation 99% is obtained, which is excellent.

2.3 The over-voltage test was conducted at 150% of input voltage (i.e. 1500 Vpp), although, since the efficiency was greater than 88%, the reduced level of 130% of input voltage could have been used. An efficiency of 96% was maintained at this level and there was no evidence of arcing or breakdown.

2.4 The test in air is not a requirement but it was interesting to determine at what level the multiplier could run before an "arc-over" would invalidate the test. The average output was 3525 volts, but one unit had an exceptionally low figure of 1600 volts.

2.5 The input capacitance of the multipliers was tested with each unit in Fluorinert FC-43 and with an input of 1000Vpp. Of the 5 pieces tested the maximum C_x was 5.8 pF which is within the specified maximum of 8 pF.

2.6 The charging current of the multipliers was measured also. Of 5 tested, 4 had values of 120µA and one was 250µA. Since the specification limit is 150µA, this last piece would be a reject on that criterion.

2.7 The maximum weight of the multipliers was measured to be 1.6 grams which is well within the limit of 5 g., although some allowance has to be made for the fact that they have not been encapsulated or coated yet and this material will add to the final tally.

2.8 The initial design of the multipliers put limits on the mechanical dimensions of .525" and .255" for length and width respectively; and limits of .042" and .039" for the thickness of capacitors and substrates, respectively. Thus the final multiplier (before encapsulating or coating) was designed to be .525" x .255" x .123". Since the specification gave dimensions of .60" x .33" x .15", there were theoretical margins of .075" x .075" x .027" on the length, width and thickness which would be allotted for the encapsulation/coating. On the 8 multipliers of design "A", the mechanical measurements were .529" x .256" x .148" maximum (without including the leads or soldering) which was already .020" over the desired thickness dimension. When one includes the leads and the solder connections the thickness of the part increases to a maximum of .182" which is .060" over the desired dimension.

Design B (Capacitors TSK 25-254 and TSK 25-255 with a glass-ceramic substrate).

2.9 Electrically, both multipliers exhibited low output voltage, high input current and a high ripple voltage and so no electrical measurements could be taken. An examination of the units on a curve tracer showed a low forward volt drop along the diode chain (e.g. 16 V compared to normal value of 25 V) indicating a short of several rectifiers in each package. Further analysis will be required to determine the exact nature of the fault.

2.10 Mechanically, the multipliers are similar to the units of design "A" (see Para 2.8 above).

Design C (Capacitors TSK 25-252 and TSK 25-253 with a glass-epoxy board substrate).

2.11 Out of four units, one piece exhibited all the same output manifestations of the "B" design multipliers, i.e. low output voltage, high input current and high ripple voltage. The other three units were acceptable electrically but the output was lower than for the design "A" multipliers. The multiplier efficiency (as defined in Para 2.1) was 94% at no load and 93% at full load of 500nA.

2.12 The load regulation was 0.9% (i.e. the output at full load is 99% of the no-load voltage).

2.13 The overvoltage test (conducted at 150% of input voltage) was satisfactory and showed a no-load efficiency of 96% on the output.

2.14 The test in air started "arcing" or "breaking down" at 3200 V minimum.

2.15 The input capacity was slightly higher than Design "A" at 5.9 pF (maximum) but this is still within specification limits.

2.16 The charging current was the same on all 3 units at 120µA which is acceptable.

2.17 Mechanically these multipliers are similar to those of the other two designs in all dimensions.

3. EVALUATION OF THE CURVED CAPACITOR BANKS

Twenty-four pieces of the TSK 25-249 (Fig. 1) curved capacitors with dumb-bell pads were received on March 8. They were mechanically inspected, with pad dimensions and location measured on 2 pieces. Electrical tests of capacitance at no bias and of the breakdown characteristics were performed on 4 samples. The capacitance measured in this test was that between the whole dumb-bell pad and the bottom electrode. It was equivalent to the sum of the capacitances of 2 capacitors in a multiplier stage, increased by the stray capacitance of the interconnection and was much higher than the theoretical single pad's capacitance of 20 pF. The results of mechanical and electrical tests are presented in Tables 7 and 8.

The average double-pad capacitance was 73.9 pF at 6KV, which is 46% higher than the average double-pad capacitance of TSK 25-250 capacitors (50.6 pF). This difference should cause no problems. To be noted is the consistency of capacitance values from pad to pad and capacitor to capacitor.

The breakdown characteristics were just satisfactory: only one pad in 24 on the 4 capacitors tested broke down below 7.8KV (D-5), but many more did not pass 9KV testing as is evidenced on the test data sheet.

4. CONCLUSIONS

Out of the 3 designs, design "A" is the best approach at this time provided that the thickness of the part can be decreased. It is thought that design "C" can be discarded at this time; there is no apparent improvement over design "A" on breakdown voltage and the capacitor is unnecessarily complicated. Final judgement on design "B" will be withheld until more units can be assembled and evaluated.

The difficulty of handling the material, low yields and considerably higher price do not justify changing to glass-ceramic at this point of time.

5. PROGRAM FOR NEXT QUARTER

1. Analyse the mode of failure of Design B rectangular multipliers, fabricate and evaluate new units.

2. Decide on the final design of rectangular capacitor banks.

3. Fabricate and evaluate curved multipliers.

4. Investigate suitable encapsulation materials and techniques.

5. Investigate means to reduce the thickness of rectangular multipliers.

6. Manufacture the First Engineering Sample of 25 each rectangular and curved multipliers.

6. PUBLICATIONS AND REPORTS

No reports or publications were made on the work associated with this program during the current quarter.

7. IDENTIFICATION OF PERSONNEL

A brief description of the background of technical personnel involved is included in the First and Second Quarterly Reports. Background of personnel added to the program during the third quarter follows.

On March 25, A. Kennedy left the employ of Erie Technological Products of Canada, and was replaced by Dr. Michael Korwin-Pawlowski as Program Manager on this contract.

During the second quarter of the program the following persons worked in their area of responsibility:

INDIVIDUAL	RESPONSIBILITY	HRS. SPENT
A. Kennedy	Program Manager (until 25 March 1977)	447
Dr. M. Korwin-Pawlowski	Program Manager (since 25 March 1977)	50
G. Gordon	Senior Electronic Engineer	54
D. Platt	Manager, Quality Assurance and Control	8
D. Archard	Senior Test Technician	30
C. Grills	Senior Engineering Technician	53
D. Regan	Senior Engineering Technician	8
F. Treverton	Senior Test Technician	12

M.L. KORWIN-PAWLOWSKI   Engineering Manager - Semiconductor Devices

PROGRAM RESPONSIBILITY: Program Manager (since 25 March 1977)

CURRENT ASSIGNMENTS:

Responsible for all engineering programs in the High Voltage Silicon Rectifier area. Since joining Erie in 1974 he has been responsible for process and new product development. Developed and put into production the following new products:

- controlled avalanche rectifiers for TV triplers and CRT power supplies.
- controlled avalanche rectifiers for TV diode split transformers.
- microwave oven rectifiers.
- X-Ray power supply rectifiers.
- low leakage rectifiers for Second Generation image intensifier tube supplies.

For the 4½ years before joining Erie, Dr. Pawlowski was doing research on InSb device technology (diffused p-n junction, MOS and Schottky-barrier devices) at the University of Waterloo. He taught electronic circuits, computer programming and numerical methods there. Prior to that he worked for 7 years in a technical R&D institute developing semiconductor devices (switching diodes, power rectifiers and thyristors, photodetectors). He was the leader of development projects on Schottky-Barrier Diodes and high-frequency surface-barrier photodetectors.

Received in 1969 the Prime Minister of Poland's Office Committee for Science and Technology Award for developing the Schottky-Barrier Diode technology.

Author of 12 original papers, 3 review papers. Holds 3 patents. Translated 2 technical books.

Member of the Association of Professional Engineers of Ontario.

ACADEMIC AND PROFESSIONAL BACKGROUND

Ph.D	-	Electrical Engineering, University of Waterloo, 1974.
M.Sc	-	Electronics, Warsaw Technical University, 1963.
Oct 1974 to date	-	With Erie Technological Products of Canada, Trenton, Ontario.
		Mar 1977 to date - Engineering Manager - Semiconductor Devices
		Oct 1974 to Mar 1977 - Senior Development Engineer - Semiconductor Devices
Nov 1969 to Sept 1974	-	University of Waterloo, Waterloo, Ontario, Graduate Research Assistant and Teaching Fellow.
Jan 1963 to Oct 1969	-	Institute of Electron Technology, Warsaw, Poland - Development Engineer - Project Leader.

C.M. GRILLS   Senior Engineering Technician

PROGRAM RESPONSIBILITY

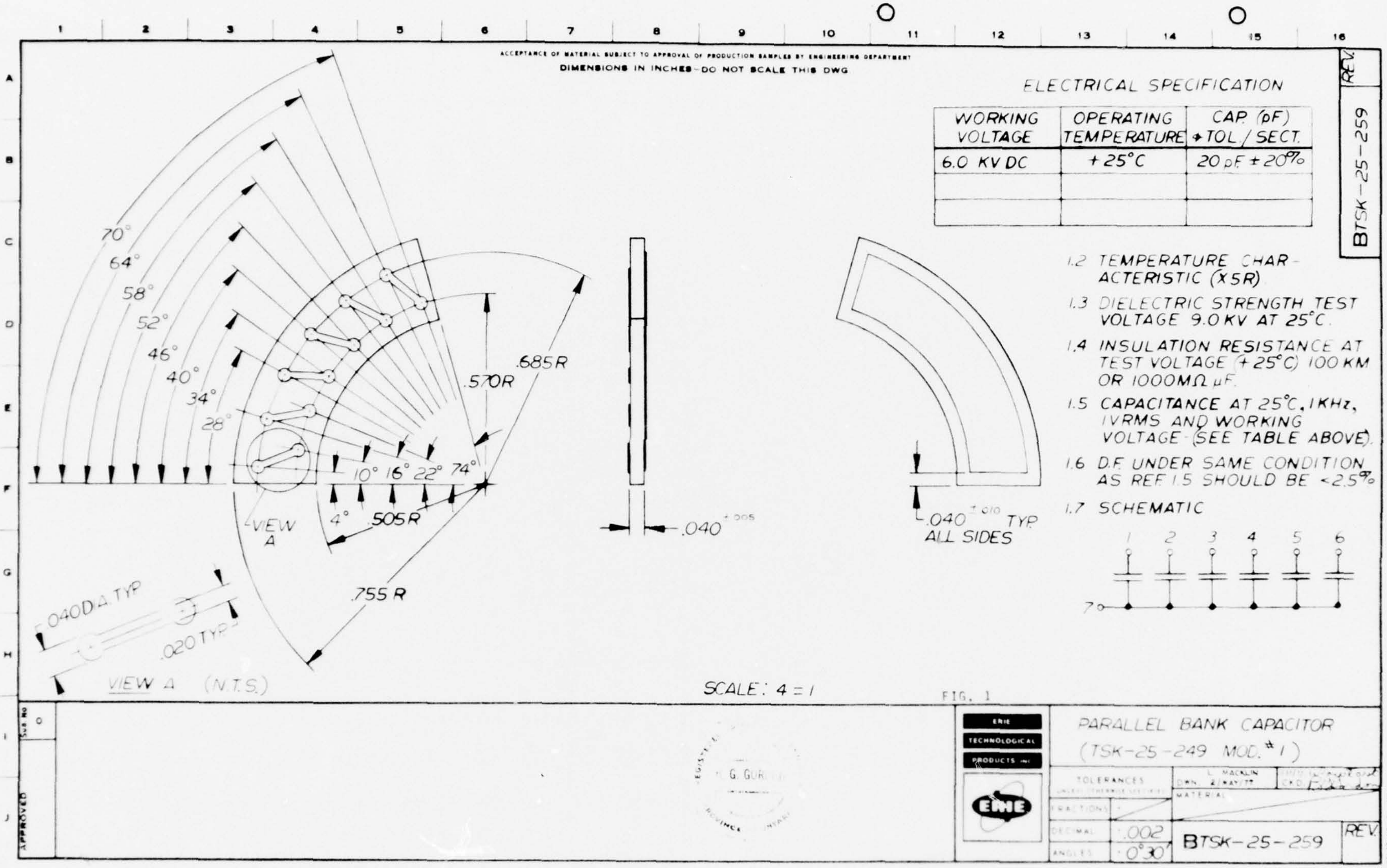
Production of substrate for voltage multiplier modules and manufacture of jigs and fixtures required for Production use.

CURRENT ASSIGNMENT

Manufacture or modification of material and components for use by High Voltage Engineering and Production Departments. Manufacture or modification of tooling, jigs and fixtures for use by High Voltage Production Departments.

ACADEMIC AND PROFESSIONAL BACKGROUND

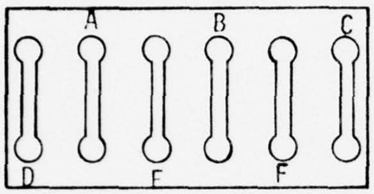
1962	Completed 4 year S.T.&T course at Moira Secondary School
1966	Certified Machinist by Ontario Dept. of Labour
1970-present	Employed as Senior Engineering Technician by Erie Technological Products of Canada Ltd.
1970	Machinist, Canadian Flight Equipment, Trenton Ontario
1967-1970	Machinist, Erie Technological Products of Canada Ltd., Trenton, Ontario
1966-1967	Machinist, Canadian Flight Equipment, Trenton, Ontario
1962-1966	Apprentice, Bata Engineering, Batawa, Ontario



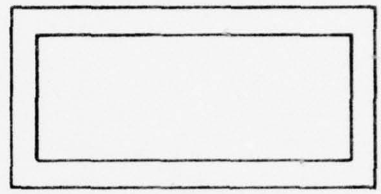
ACCEPTANCE OF MATERIAL SUBJECT TO APPROVAL OF PRODUCTION SAMPLES BY ENGINEERING DEPARTMENT
DIMENSIONS IN INCHES—DO NOT SCALE THIS DWG
ELECTRICAL SPECIFICATION
WORKING VOLTAGE | OPERATING TEMPERATURE | CAP (pF) ± TOL./SECT.
6.0 KV DC | +25°C | 20 pF ± 20%
1.2 TEMPERATURE CHARACTERISTIC (X5R)
1.3 DIELECTRIC STRENGTH TEST VOLTAGE 9.0 KV AT 25°C.
1.4 INSULATION RESISTANCE AT TEST VOLTAGE (+25°C) 100 KM OR 1000MΩ μF.
1.5 CAPACITANCE AT 25°C, 1 KHz, 1 VRMS AND WORKING VOLTAGE (SEE TABLE ABOVE).
1.6 D.F. UNDER SAME CONDITION AS REF 1.5 SHOULD BE <2.5%
1.7 SCHEMATIC
1 2 3 4 5 6 7
BTSK-25-259
REV.
70° 64° 58° 52° 46° 40° 34° 28°
4° 10° 16° 22° 74°
.685 R
.570 R
.505 R
.755 R
VIEW A
.040 ±.005
.040 ±.010 TYP. ALL SIDES
.040 DIA. TYP
.020 TYP
VIEW A (N.T.S.)
SCALE: 4 = 1
FIG. 1
ERIE TECHNOLOGICAL PRODUCTS INC.
PARALLEL BANK CAPACITOR (TSK-25-249 MOD. #1)
TOLERANCES
FRACTIONS ±
DECIMAL ±.002
ANGLES ±0°30'
MATERIAL
BTSK-25-259
APPROVED

CHARACTERISTICS OF A TSK 25-250 CAPACITOR BANK SAMPLE

View from Top



View from Bottom

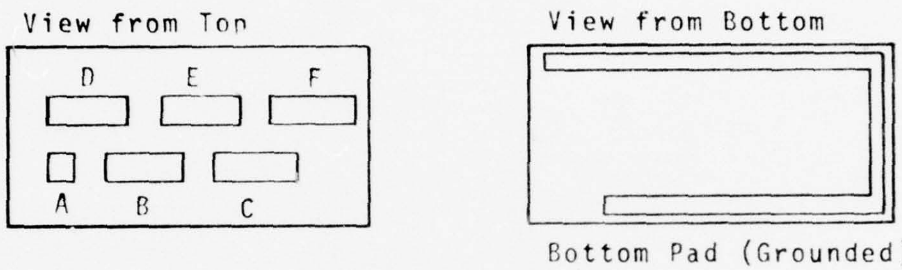


Bottom Pad (Grounded)

PAD	C_x @ no bias (pF)	D.F. (%)	C_x @ 6kV (pF)	LEAKAGE CURRENT @ 6kV (nA)	V_B (kV)	FLASH-TEST @ 9kV
A	79.4	0.41	55.6	2.5	8.0	N.A.
B	86.6	0.90	60.6	4.5	PASS	FAIL
C	53.1	0.26	37.2	2.5	PASS	PASS
D	53.6	0.35	37.5	3.2	PASS	PASS
E	86.0	0.32	60.2	6.0	PASS	FAIL
F	75.2	0.36	52.6	3.5	9.0	N.A.

TABLE 1

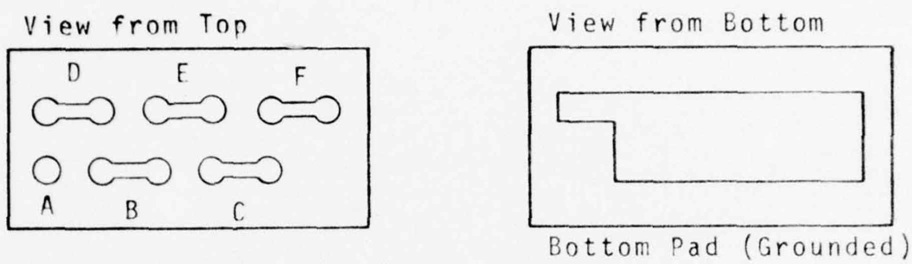
CHARACTERISTICS OF A TSK 25-253 CAPACITOR BANK SAMPLE



PAD	C_x @ no bias (pF)	D.F. (%)	C_x @ 6kV (pF)	LEAKAGE CURRENT @ 6kV (nA)	V_B (kV)	FLASH-TEST @ 9kV
A	40.3	0.37	28.2	2.5	PASS	PASS
B	65.2	0.32	45.6	5.0	PASS	FAIL
C	61.4	0.24	43.0	4.0	PASS	PASS
D	66.3	0.49	46.4	12.0	PASS	PASS
E	64.9	0.32	45.4	12.0	PASS	PASS
F	53.9	0.21	37.7	5.5	PASS	PASS

TABLE 2

CHARACTERISTICS OF A TSK 25-255 CAPACITOR BANK SAMPLE



PAD	C_x @ no bias (pF)	D.F. (%)	C_x @ 6kV (pF)	LEAKAGE CURRENT @ 6kV (nA)	V_B (kV)	FLASH-TEST @ 9kV
A	34.3	0.26	24.0	2.8	PASS	PASS
B	78.4	0.31	54.9	4.0	PASS	FAIL
C	76.4	0.28	53.5	4.0	8.7	N.A.
D	72.8	0.37	51.0	4.8	8.4	N.A.
E	80.3	0.34	56.2	4.3	PASS	PASS
F	72.2	0.43	50.5	10.0	PASS	PASS

TABLE 3

RESULTS OF OPERATIONAL TESTS FOR RECTANGULAR MULTIPLIERS

		UNIT #6		UNIT #7	
V_i (V_{p-p})	I_L (nA)	V_o (kV)	η (%)	V_o (kV)	η (%)
200	0	1.17	97.5	1.14	95.0
500	0	2.92	97.3	2.89	96.3
800	0	4.65	96.9	4.61	96.0
1000	0	5.75	95.8	5.70	95.0
1000	500	5.70	95.0	5.65	94.2

NOTE: f = 40KHz
Testing done in free-air, except for
V_i = 1000V when done in Fluorinert FC-43.

TABLE 4

ELECTRICAL CHARACTERISTICS OF RECTANGULAR MULTIPLIERS

DESIGN	UNIT #	Vo, (kV) @ Vi=1KV $I_L=0$	η (%)	Vo, (kV) @ Vi=1kV I_L=500nA	η (%)	Vo, (kV) @ Vi=1.5kV $I_L=0$	V_r, (Vpp) @ Vi=1kV $I_L=0$	Ci, (pF) @ Vi=1kV $I_L=0$	ic, (μA) $I_L=0$
	8	5.8	96.7	5.75	95.8	8.75	20.9	-	-
	9	5.8	96.7	5.75	95.8	8.70	20.1	5.4	120
	10	5.8	96.7	5.75	95.8	8.70	22.0	-	-
A	11	5.8	96.7	5.75	95.8	8.65	18.9	5.8	120
	12	5.8	96.7	5.75	95.8	8.70	20.8	-	-
	13	5.8	96.7	5.75	95.8	8.70	19.5	5.4	120
	14	5.8	96.7	5.75	95.8	8.65	18.9	5.4	250
	15	5.8	96.7	5.75	95.8	8.70	21.5	5.4	120
	19	5.65	94.2	5.60	93.3	8.60	19.5	5.8	120
C	20	5.65	94.2	5.60	93.3	8.60	19.5	5.7	120
	21	5.65	94.2	5.60	93.3	8.60	20.1	5.9	120

NOTES: f = 40KHz, except for C_i test where f = 20KHz
Units immersed in Fluorinert FC-43
V_c measured using Jennings Probe - Erie TEX 105-300
For Test circuit see Fig. 5 of Second Quarterly Report

TABLE 5

DIMENSIONS AND WEIGHT OF RECTANGULAR MULTIPLIERS

DESIGN	UNIT #	LENGTH (inch)	WIDTH (inch)	THICKNESS (body) (inch)	THICKNESS (including soldered lead) (inch)	WEIGHT (gram)
A	8	0.523	0.254	0.146	0.182	1.51
	9	0.521	0.253	0.144	0.170	1.58
	10	0.521	0.251	0.148	0.171	1.60
	11	0.529	0.253	0.143	0.172	1.57
	12	0.526	0.252	0.143	0.177	1.51
	13	0.522	0.252	0.141	0.166	1.58
	14	0.519	0.252	0.142	0.182	1.59
	15	0.517	0.256	0.147	0.182	1.63
B	16	0.525	0.253	0.133	0.163	1.60
	17	0.524	0.254	0.142	0.178	1.61
C	18	0.519	0.252	0.139	0.163	1.56
	19	0.518	0.251	0.141	0.178	1.58
	20	0.522	0.255	0.147	0.177	1.58
	21	0.520	0.252	0.143	0.172	1.57

TABLE 6

TSK 25-249

DIMENSIONING OF CURVED BANK CAPACITORS

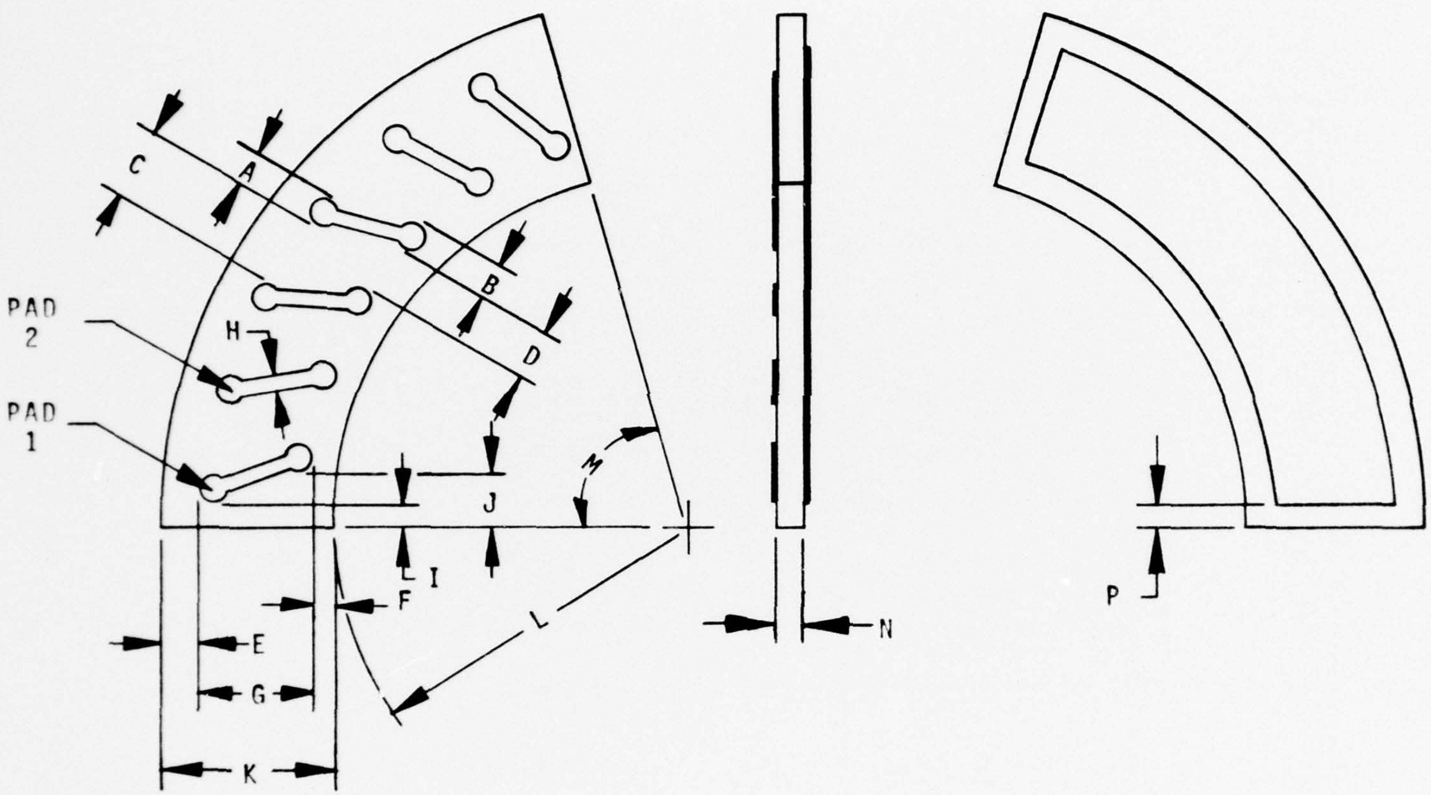


FIG. 2

MECHANICAL INSPECTION DATA FOR TSK 25-249 CAPACITOR BANKS

UNIT 1

PAD #	1	2	3	4	5	6
Dimensions in inches						
A	.0526	.0519	.0516	.0524	.0528	.0532
B	.0526	.0527	.0513	.0522	.0521	.0530
C	.0897	.0688	.0912	.0915	.0916	
D	.0653	.0674	.0653	.0675	.0671	
E	.0471	.0417	.0447	.0430	.0427	.0429
F	.0331	.0344	.0349	.0335	.0348	.0353
G	.1887	.1891	.1890	.1894	.1897	.1893
H	.0227	.0215	.0228	.0212	.0225	.0227
I	.0271					.0879
J	.0757					.0078
K	.249					.251
L&M	OK					
N	.0410					
P min	.0223					

NOTE: Radius L (.505R) and angle M (74°) checked against template.
See Figure 2 for dimensioning.

TABLE 7A

MECHANICAL INSPECTION DATA FOR TSK 25-249 CAPACITOR BANKS

UNIT 2

PAD #	1	2	3	4	5	6
Dimensions in inches						
A	.0526	.0527	.0529	.0527	.0530	.0508
B	.0536	.0537	.0525	.0532	.0531	.0529
C	.0918	.0922	.0906	.0921	.0931	
D	.0650	.0672	.0645	.0672	.0662	
E	.0512	.0726	.0450	.0426	.0400	.0406
F	.0229	.0266	.0296	.0328	.0110	.0402
G	.1888	.1895	.1903	.1892	.1892	.1880
H	.0220	.0221	.0226	.0220	.0228	.0230
I	.0230					.0935
J	.0752					.0089
K	.247					.250
L&M	OK					
N	.041					
P min	.0222					

NOTE: Radius L (.505R) and angle M (74°) checked against template.
See Figure 2 for dimensioning.

TABLE 7B

ELECTRICAL TEST DATA FOR TSK 25-249

CURVED CAPACITOR BANK SAMPLES

UNIT #	PAD #	C_x @ 0kV (pF)	D.F. (%)	C_x @ 6kV (pF)	V_B (kV)
1	1	105.1	0.37	73.6	9.0
	2	110.1	0.43	77.1	9.0
	3	109.4	0.41	76.6	7.6
	4	110.1	0.37	77.1	9.0
	5	110.0	0.38	77.1	8.7
	6	103.9	0.36	72.7	8.5
2	1	101.1	0.38	70.8	9.0
	2	107.7	0.37	75.4	14.3
	3	107.4	0.37	75.2	14.0
	4	108.9	0.44	76.2	9.0
	5	110.4	0.40	77.3	9.0
	6	103.8	0.40	72.7	13.4
3	1	98.8	0.33	69.2	12.4
	2	106.0	0.33	74.2	13.4
	3	104.8	0.35	73.4	8.8
	4	105.0	0.30	73.5	10.8
	5	106.7	0.31	74.7	9.0
	6	100.6	0.31	70.4	9.2
4	1	100.4	0.41	70.4	9.0
	2	107.3	0.38	75.2	9.0
	3	105.5	0.67	73.9	9.0
	4	106.6	0.41	74.6	9.8
	5	102.8	0.41	72.0	7.3
	6	101.8	0.39	71.3	8.6
Average		105.8	0.37	74.0	9.9

TABLE 8

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